Development of Vertical Alignment System for Manufacturing AMOLED TV

Yoon-Seok Lee*[1]*, Seok-Yoon Han, Nam-Hoon Lee, Jeong-Og Choi
[1]**R&D Center, Doosan Mecatec Co. Ltd., Banwol Ind. Estate 3-22, 397-2, Ansan-Si, Gyeonggi-Do, Republic of Korea**
Tel.:82-31-599-2484, E-mail: lysh04@doosan.com

Keywords: OLED, Alignment System, Equipment

Abstract

We once have announced that we developed a horizontal large-area alignment system with an alignment accuracy of < ±3 μm and an alignment time of < 30 seconds, a core process module for RGB direct pattering by using a fine metal mask, which can process a Gen 4 (730 × 920 mm^2) substrate for high resolution OLED products.
In this article, we presents a brand-new vertical alignment system for a even larger substrate of Gen 5 and beyond which can provide a better alignment accuracy and a higher throughput. The newly developed system exhibits an alignment accuracy of < ±2 μm and an alignment time of < 20 seconds which, we believe, can open a new era for manufacturing large-size OLED monitors and TVs.

1. Introduction

Recently, OLED display makers are rushing to keep up with the expanded markets for LCD and PDP TVs through media or other means such as exhibitions. Sony presented an 11-inch AMOLED TV set, and Samsung Mobile Display showcased its 40-inch full color AMOLED at an exhibition, unveiling their roadmap for the development of 14-, 15-, and 21-inch AMOLED displays in 2009 and larger 40- and 42-inch AMOLED displays in 2010. CMEL who had already developed 25-inch AMOLED is boasting that they are able to mass-produce AMOLED TV from later in 2009. Seiko Epson also developed an 8-inch top emissive panel to replace small-size LCDs which are usually used at retail outlets, including car navigation systems, and released its plan to expand into the 21-inch panel market in the near future. As described, many of OLED display makers focus on the development of large-sized, high-definition and high-resolution products.

As we reported in IMID 2008, we developed using a 4th (730 × 920 mm^2) generation substrate, and described the technological aspects. Also, we announced that the horizontal alignment system for 4thgeneration substrates had achieved an alignment accuracy of < ±3 μm and an alignment time of < 30 seconds [1].

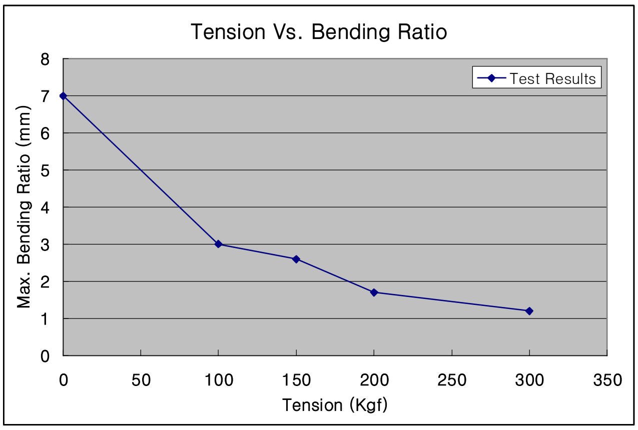
In this study, we describe a vertical type alignment system which can use a 5th (1100 × 1300 mm^2) generation substrate of production large size AMOLED.

We conducted a pilot study with the 5th generation substrate to observe the gravity effect and established the concepts of substrate transfer and alignment with keeping the substrate vertically. In this study, we provides technological information on a substrate transfer apparatus required for the development of a vertical-type alignment system and describes pre-alignment methods, the improved performance of a vision system, and the results of stage accuracy test and alignment accuracy test. In addition, we described the analysis of alignment flow and tact time.
Currently we are developing a high-efficiency sideway deposition source in parallel with the development of a vertical type alignment system and its integration [2].

2. Experiments and Discussions

2-1. Analysis of substrate sagging

We designed the vertical alignment system for 5th generation substrates to minimize the substrate sagging less than 1.2mm by using the stretching method, but in case of 4th generation horizontal system, we could obtain 1.5mm of sagging height by using clamping method. Figure 1 shows sagging height in our horizontal system.

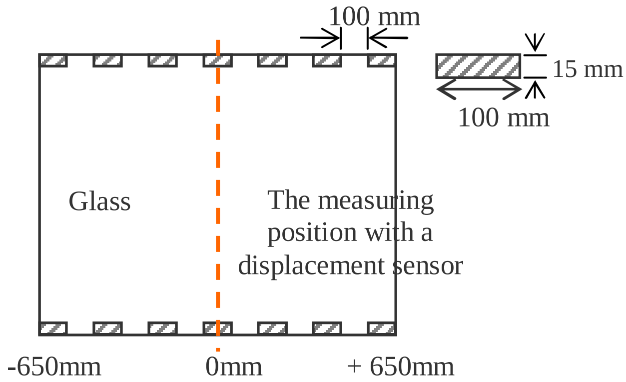


[Figure 1] Test results of the horizontal 5th generation substrate sagging height

The tension of 0 indicates a substrate sagging under the clamping method

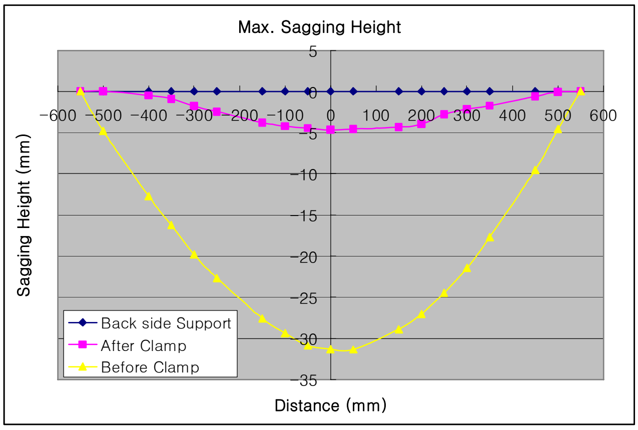
The stretching method can minimize substrate sagging, but it may increase process time and make the system more complex. Therefore we need a brand-new concept to simplify the system configuration, save the process time, and minimize the substrate sagging. So we designed an alignment system that could align a substrate and a mask vertically.

The sagging height was measured with the substrate inclined at five degrees. For the substrate support and clamping component, seven support plates of 100 mm x 15 mm were set up on the top and bottom sides of the substrate, at 100 mm intervals in a range of 1300 mm. The substrate was clamped at the same position using a clamping unit of 100 mm x 10 mm. The measurements were carried out under the test conditions with the substrate placed and clamped on its support. A laser displacement sensor (KYENCE, LK-G150) was also used to measure the sagging height in vertical direction (dotted line) in the middle part where the maximum sagging height can be monitored (Figure 2).



[Figure 2] Structure and arrangement of the clamping component

Figure 3 shows the changes in substrate sagging height between before and after clamping. The sagging height was measured to be 31 mm before clamping and 4.6 mm after clamping. The measured sagging height values were less satisfactory compared to the horizontal 4th generation system. However, the vertical 5th generation system allows the insertion of a support that keeps the substrate flat. In this system, we could eliminate the sagging issue by supporting the back side of substrate to make the substrate flat.

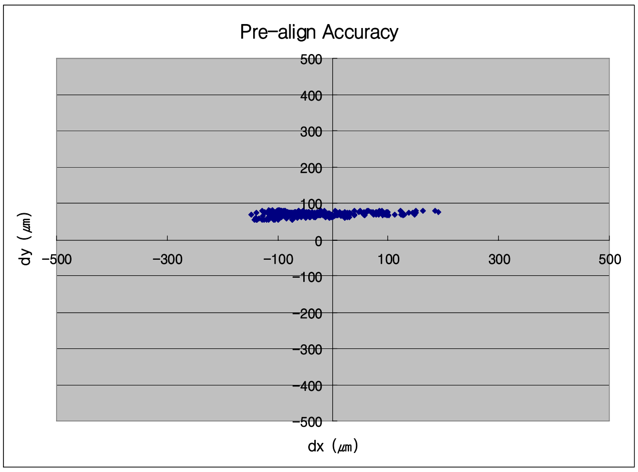


[Figure 3] Comparison of sagging height before and after clamping

2-2. Pre-alignment Method

The conventional pre-alignment methods for the substrates transferred by a robot are using a tapered holder, centering by additional jigs, and precise pre-alignments with CCD cameras. The use of a tapered holder greatly relies on the accuracy of the robot that loads substrates. It is the simplest method, but if the robot repeatability or reliability is not good enough during loading, the substrates can be damaged. Pre-alignment by centering is most extensively used. It is a quite simple apparatus and effective pre-alignment can be done. Recently, in order to get better alignment accuracy, narrow FOV (Field of View) is preferred. Therefore, pre-alignment with CCD cameras is sometimes used, but this method is mechanically more complicated and takes more time than the previous two methods.

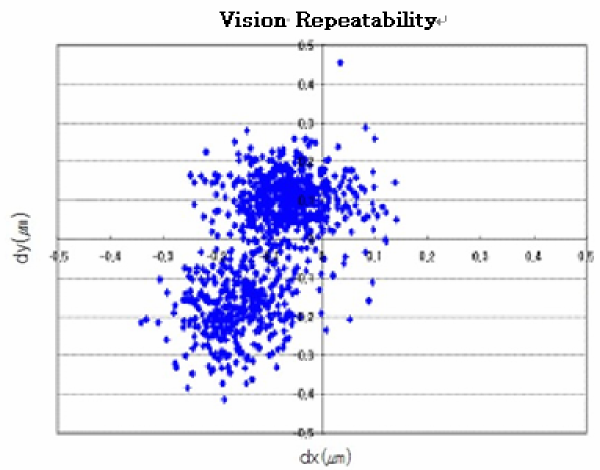
We used a stopper unit as pre-alignment apparatus for fast processing and mechanical simplicity. The stopper could make the substrate stop at a certain position transferred by the conveyor. Figure 4 shows the result of pre-align accuracy we tested. As shown in figure 4, Y-axis indicated the similar values because the substrates are put on the conveyor, but X-axis had some deviations due to the repulsive force when the substrates are stopped by a stopper. It can be controlled by the deceleration time of the conveyor. In this system, FOV of the vision is 2.30 x 2.39 mm^2 and it shows that all of alignment keys of the substrates are in the vision after 300 times of pre-alignment so it could be used as the simplest and most effective pre-alignment method.



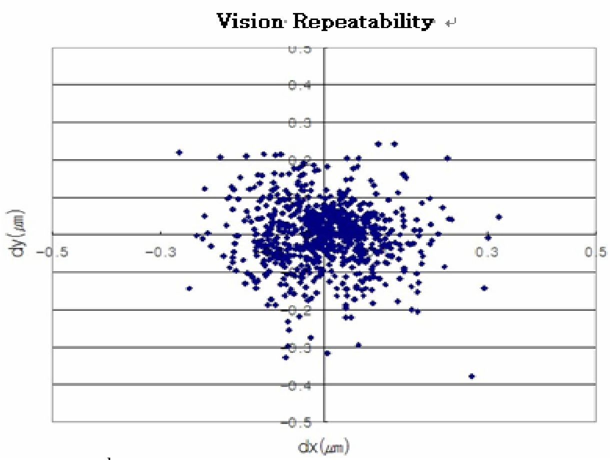
[Figure 4] Pre-alignment accuracy

2-3. Comparison of Vision Repeatability

This system used optical CCD cameras to recognize the keys of substrates and a mask. In order to avoid the interference with the apparatus in the chamber, 476mm working distance and 2.6mm depth of CCDs were selected, which have 1038 x 1035 pixels resolution and 2.30 x 2.39 mm^2 FOV. That is, 1 pixel is 2.3 x 2.3 μm^2 and it is divided by 10 in the software so it has 0.23 x 0.23 μm^2 sub-pixels. We installed these CCD cameras out of the chamber and photographed through the view ports. For vivid images, we used external LED lights, which can control intensity of illumination with coaxial lighting. In order to measure vision repeatability, we tested 800 times repeatedly after alignment was completed with the same substrate and the same mask. The repeatability was less than ±0.4 μm as shown in Figure 5-(b). Figure 5-(a) shows the measuring result in the 4th generation horizontal alignment system.[1] We obtained the similar results from the two systems, which were caused by the deviation of vision accuracy of less than 2 sub-pixels (Sub-pixel size of this system: 0.23 μm) due to the external vibration, accuracy of key configuration, and accuracy of key recognition.



(a) 4th generation horizontal alignment system



(b) 5th generation vertical alignment system

[Figure 5] Comparison of vision accuracy

2-4. Analysis of Stage Accuracy

Stage accuracy is one of major factors that have the biggest influence on the accuracy of the alignment system. We employed the UVW method to move the stage that is operated by a servo motor. And we used a servo motor of 8kw capacity for 4 axes in order to stand the greater load than a general horizontal stage.

We tested and measured, moving forward and backward repeatedly (moving by + 200 µm first and then, -200 µm after reaching at 1000 µm). In the relevant sections, less than ±2 µm of error was found. It means that the stage used in this study has reliability for the alignment system. Table 1 shows the stage position accuracy of repeatability.

2-5. Comparison and Analysis of Alignment Accuracy

As a result of the alignment test after loading 100 sheets of substrates, alignment accuracy of < ±3 µm was found as shown in Figure 6. Figures 6 and 7 compare the alignment accuracy data of a vertical and a horizontal type. We tested vertical alignment system with larger substrate than horizontal alignment system, but we could obtain the better results in spite of using the components with similar specifications.[1]

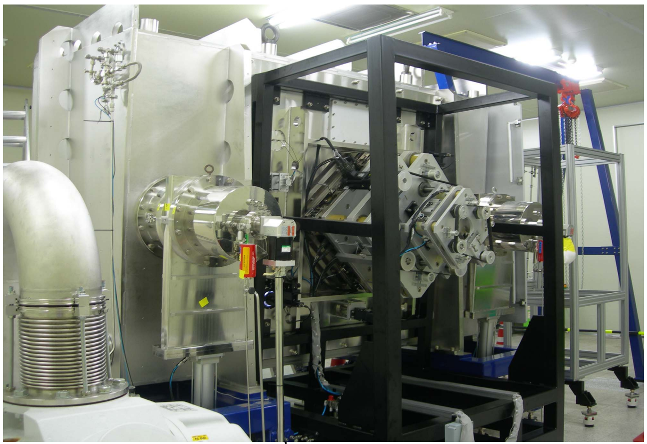
(Unit: µm)

X-Axis	0	200	400	600	800	1000
(+direction)	0.0	198.5	398.9	598.9	798.8	998.8
(-direction)	1.9	198.2	398.5	598.5	798.4	
(+direction)	0.0	198.3	398.7	598.8	798.7	998.6
(-direction)	1.8	198.2	398.5	598.5	798.7	
(+direction)	0.0	198.3	398.7	598.9	798.8	998.9
-direction)	1.8	198.2	398.5	598.6	798.7	

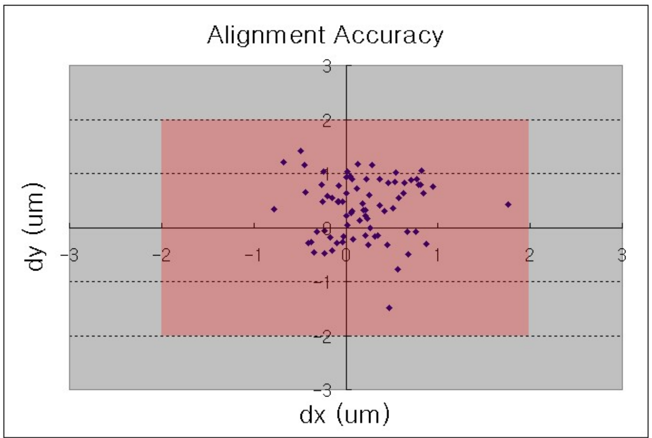
Y-axis	0	200	400	600	800	1000
(+direction)	0.0	198.5	398.8	598.9	801.2	1001.3
(-direction)	1.1	201	401	598.8	801.1	
(+direction)	0.0	198.7	398.9	601.1	801.3	1001.3
(-direction)	1.1	198.9	398.9	598.9	801.1	
(+direction)	0.0	198.7	398.9	601.2	801.3	1001.3
(-direction)	1.1	198.9	398.8	598.8	801.1	

XY-axis	0	200	400	600	800	1000
(+direction)	0.0	198.9	401.2	598.6	801.1	998.9
(-direction)	1.2	198.4	398.4	598.5	798.6	
(+direction)	0.0	198.8	401.0	598.5	801.0	998.8
(-direction)	1.2	198.5	398.5	598.4	798.6	
(+direction)	0.0	198.9	398.9	598.5	801.0	998.8
(-direction)	1.2	198.5	398.5	598.5	798.6	

[Table 1] Stage position accuracy

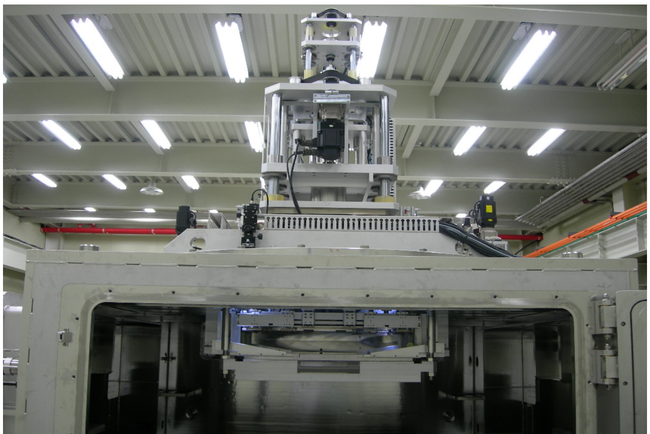


(a) 5th Vertical Aligner

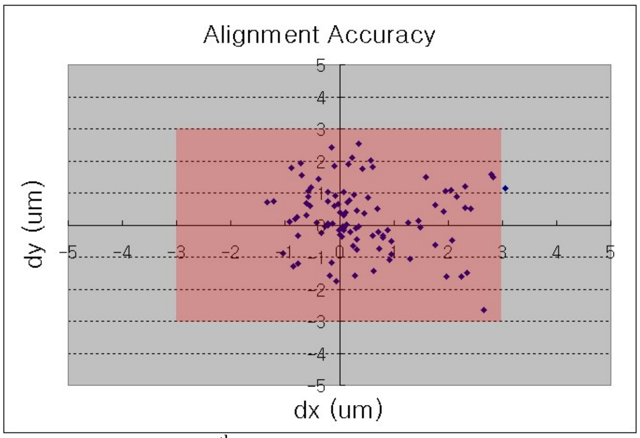


(b) 5th Alignment Accuracy

[Figure 6] Vertical alignment system



(a) 4th Horizontal Aligner



(b) 4th Alignment Accuracy

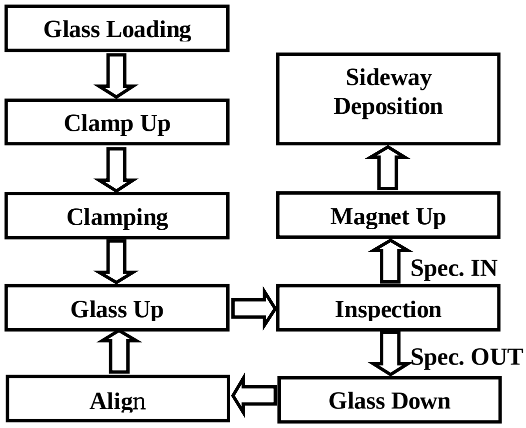
[Figure 7] 4th Horizontal alignment system

Because if we contact the substrate with the mask in the horizontal type, a part of the substrate that is bent touches the mask first in, and it causes slip of substrate. However, in the case of the vertical type, substrate sagging doesn't take place so we can align substrate and mask more accurately. That is, under the circumstance that the substrate and mask keep closer during alignment process, mechanical errors can be minimized.

2-6. Analysis of Alignment Flow and Tact Time

In order to minimize the substrate transfer time and ready time for alignment, we designed the substrates to be directly loaded into the alignment system at the same angle, 5 degrees, and in order to suppress the generation of particles in vacuum environment, we used magnet rollers. The maximum speed of transfer was set at 130mm/sec. For the case that the width of a chamber is 2800mm, we designed the substrate loading to be done within 23 seconds.

Table 2 shows the flow chart of the alignment process from substrate loading to before-deposition. Table 3 shows the average process time step by step when 100 sheets of substrate were loaded. It indicates that the average time for all the processes is finished in 19.95 seconds.



[Table 2] Alignment flow chart

Step	Time(sec)
Clamp Up	2.85
Clamping ~ Glass Up	5.73
Align ~ Inspection	8.76
Magnet Up	2.61
Total	19.95

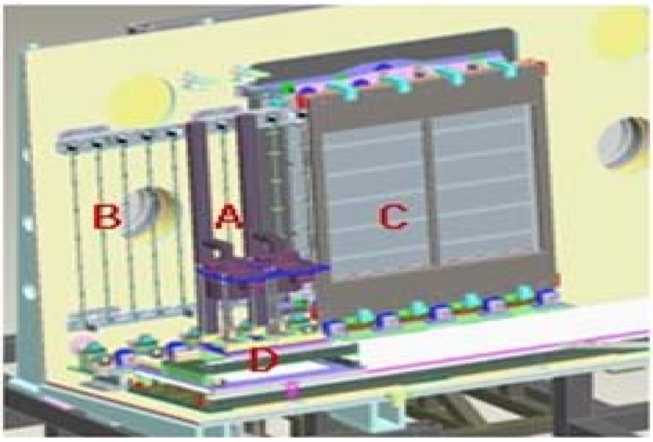
[Table 3] Average operating time obtained by testing 100 sheets of substrates

In the analysis of tact, the average alignment time covers glass down, alignment, glass up, inspection, and result which is in the designated specification. It shows the average process time of 19.95 seconds, which is about 2.15 seconds faster than the optimized process time, 22.1 seconds, of the 4th generation horizontal alignment system that we had presented previously. As mentioned above, since we could use the substrate that is maintained flat, which minimizes the distance between the mask and the substrates, we could save the working time of the apparatus, as well as the time taken for substrate loading and pre-alignment.

2-7. Concept of Vertical Deposition System

Figure 8 shows a vertical deposition system we are developing which can deposit organic material evenly on the substrate preventing substrate sagging due to gravity. It contains a sideway deposition source, substrate loading system, vertical alignment system and source scanning unit.

(a) Picture of System



(b) Configuration of System

A. Sideway deposition source (for 5th generation substrate); **B**. Substrate loading system; **C**. Vertical type alignment system, **D**. Source scan unit

[Figure 8] Vertical deposition system

4. Summary

Through this study, we developed the vertical alignment system using the 5th (1100×1300mm^2) generation substrates, and as a result, we obtained alignment accuracy of < ±2 µm and alignment time of < 20 seconds, so we could enlarge the substrate size and improve the alignment accuracy compared with horizontal type alignment system. We are also developing a brand-new sideway deposition source which can meet 5th or later-generation. And we expect to provide the key technologies for developing and manufacturing AMOLED TV with this source and alignment system.

Acknowledgement

We feel thankful for Dr. Ho-Sun Shin who gave advice and support to us while we were working on this project. We also would like to give our thanks to our colleagues, Hae-Won Kim and Jae-Yong Park who helped with manufacturing this system, making data, and writing this paper. This work was also supported by the Korean Ministry of Knowledge Economy's program for the development of a high-precision manufacturing robot system.

5. References

1. Jae-Yong Park, Seok-Yoon Han, Nam-Hoon Lee, Jeong-Og Choi, Ho-Sun Shin, *IMID'08 Technical Digest*, p. 873 (2008)

2. Hae-Won Kim, Seok-Yoon Han, Jeong-Ok Choi, *SID '09, The 9th International meeting on Information Display*, p. 1359 (2009)